Papers and Reports

Observations on the effects of immersion in Bath spa water

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Abstract

Immersion in water in spas has been practised for centuries and has many proponents. Despite fierce debate about its efficacy there has been little scientific evaluation of the effect of immersion in mineral waters. Eight normal subjects were immersed in Bath spa water for two hours and the renal, haematological, and cardiovascular responses were compared with those in the control periods before and after immersion. Significant, twofold diuresis and natriuresis, 5% haemodilution, and a 50% increase in cardiac index were observed in subjects immersed, sitting, in Bath spa water at 35°C. These changes may constitute part of the scientific rationale for spa treatment in many states of disease.

Introduction

James Crook of Long Acre, had dropsy, jaundice, palsy, rheumatism and an inveterate pain in his back.

In three immersions, the swellings of his legs sunk, so did the pain of his back, as did the jaundice, blowing from his nose a great quantity of bilious yellow matter. From the rigidity and the pressure of the fluid, we may account for his pissing more than he drank.

A SUTHERLAND, 1764[1]

Despite extensive use throughout the centuries and many claims on its behalf (fig 1)[1] it has only been with the advent of the manned space flight programme that a thorough scientific evaluation of the physiology of immersion in water began.[2] An understanding of the changes induced by immersion became important as it was used as a model of weightlessness for experiments and training astronauts (fig 2).[2,3]

Immersion in water produces profound changes, including diuresis, increased sodium excretion, increased potassium excretion,[2] and an increase in cardiac output.[3-5] We investigated these changes in normal subjects undergoing immersion in Bath spa water.

[The illustration on the front cover is of the Pump Rooms at Bath.]

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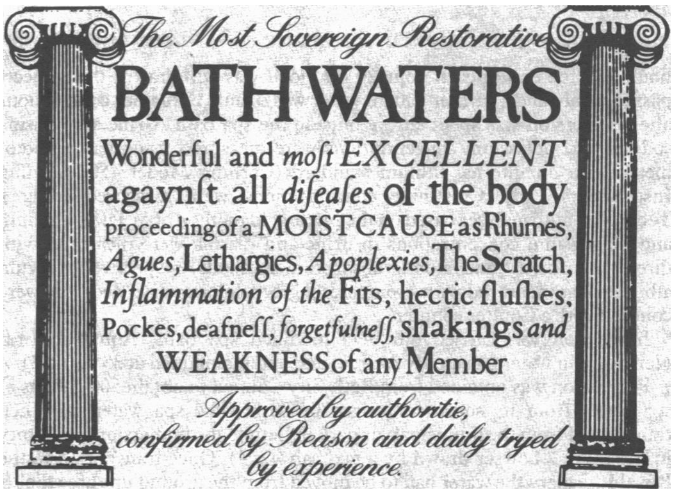

FIG 1—Eighteenth century Bath postcard.

Patients and methods

Studies of immersion were carried out in eight normal subjects, four men and four women, age range 20-56 years. Subjects were maintained on a normal diet but asked to maintain an identical diet for two days before the study began.

Subjects arose at 7 30 am and ingested 400 ml water. At 8 30 am they passed urine and a further 200 ml water was drunk. After a control hour before immersion sitting outside the spa bath subjects entered the spa bath at 9 30 am and remained seated, immersed to the suprasternal notch, for two

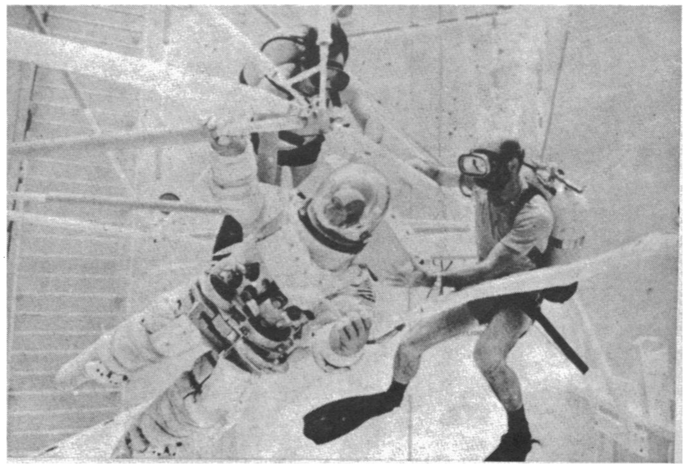

FIG 2—Immersion of astronaut under water.

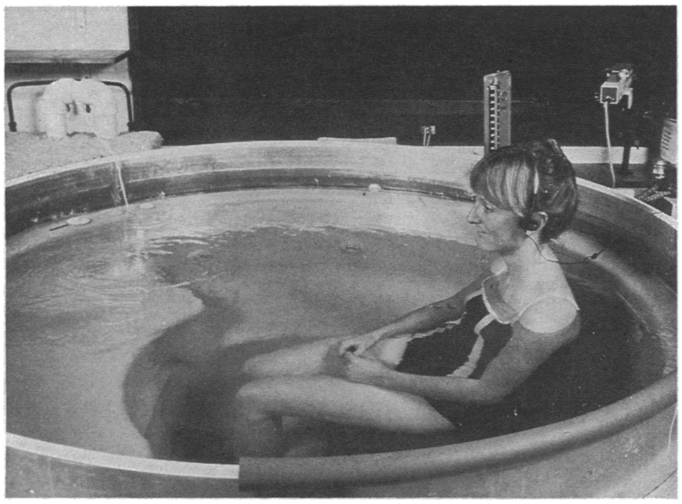

FIG 3—Subject in spa bath.

hours. At the end of each hour 20 ml blood was withdrawn, the subjects passed urine, and a further 200 ml water was drunk. A further control hour after immersion was spent sitting outside the spa bath. Urine and plasma sodium and potassium concentrations were measured using flame photometry with an internal lithium standard (Corning Model 450, Corning Instruments Ltd). Creatinine concentrations were measured using a Technicon autoanalyser based on the picric acid method of M Jaffé. Calcium and magnesium concentrations in urine and plasma were measured with direct colorimetry and atomic absorption methods, respectively. Serum albumin was measured with bromocresol green colorimetry. Red cells were counted with a Coulter counter.

Immersion was carried out in a modified spa bath (Aquatech Ltd, Newbury) in water constantly recirculated and maintained at 35°C (fig 3).

Permission was obtained from Bath City Council to obtain 500 gallons of spa water from its source of origin in Bath. The spa water was then transported from the municipal car park in Bath to the immersion laboratory in Bristol in a bowser drawn by a taxi cab (fig 4). Once transported to the Royal Infirmary the water had to be moved from the ground up three flights to the immersion laboratory on the research floor. With a submersible pump we tried to pump the water up the vertical height of 70 feet and then into the spa bath. After 10 minutes pump failure supervened, and as attempts at resuscitation failed the water was transported manually by healthy volunteers in plastic bins on trolleys using the hospital goods' lifts.

Cardiac output was measured with a pulsed wave Doppler blood velocity meter (Pedof) to obtain signals of ascending aortic blood velocity. From these signals mean aortic velocity was determined with a microcomputer to analyse the wave form, and the cardiac output was calculated as the product of mean aortic velocity and aortic cross sectional area. This method is reported to correlate well with both rebreathing and thermodilution techniques ($r=0.97$, $p<0.001$).[6] As the subjects acted as their own controls we assumed that the aortic cross sectional area was constant. As the important variable to study was the relative changes on immersion the men were ascribed an aortic diameter of 28 mm and women 27 mm. We thus described our results in terms of changes in cardiac index rather than measurements of absolute cardiac output.

Data are expressed as means (SEM). Statistical analyses were performed using paired t tests for parametric data and the Mann-Whitney U test for non-parametric data.

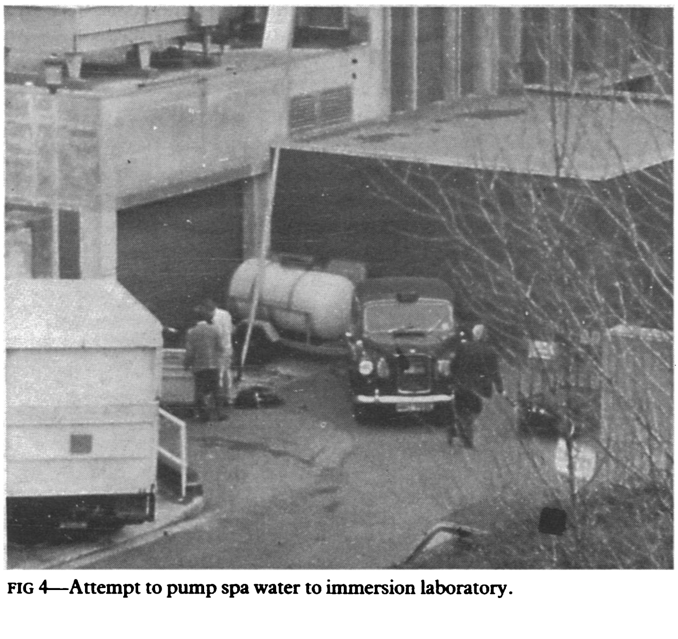

FIG 4—Attempt to pump spa water to immersion laboratory.

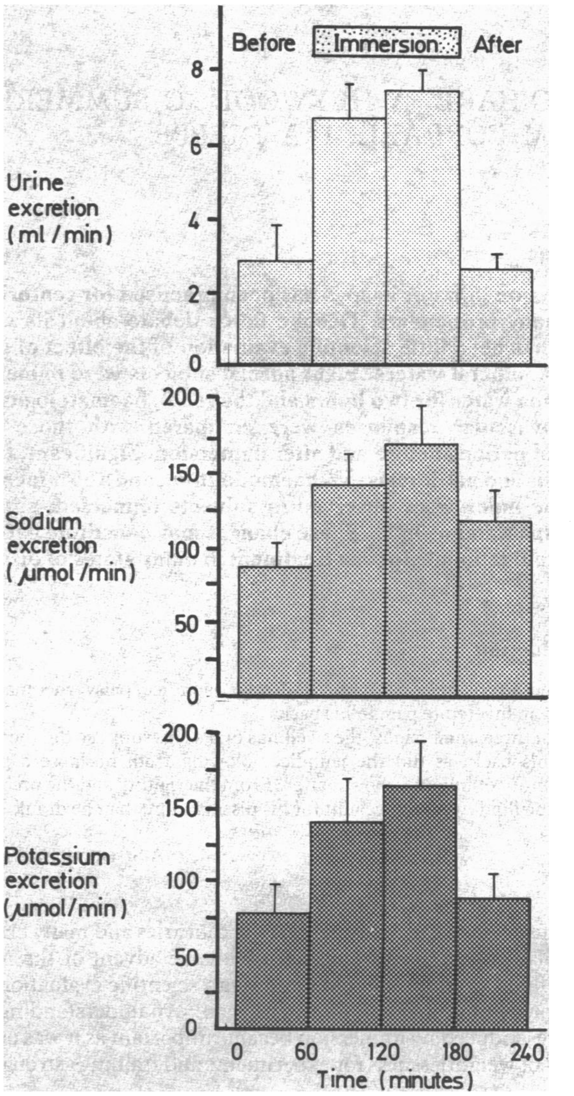

FIG 5—Renal response to immersion in spa water.

Results

Renal changes

Immersion in Bath spa water resulted in highly significant diuresis compared with the control state before immersion ($p<0.01$). The mean (SEM) total excess volume of water excreted as a result of immersion over the two hour period was 510 (85) ml. A twofold increase in sodium excretion resulted from immersion (the rate before immersion was 86 (15) µmol/min and 170·8 (29) µmol/min during the second hour) ($p<0.01$) (fig 5). A significant increase in potassium excretion was also observed on immersion and was of the same amount as the sodium excretion (from 78·6 (19) µmol/min before immersion to 156·2 (28) µmol/min by the second hour) ($p<0.01$). A mean loss of weight of 0·53 (0·14) kg occurred. This corresponds with the losses of water from diuresis and also some loss from sweating. No significant change was seen in creatinine clearance throughout immersion, which ranged from mean values of 109 to 121 ml/min (fig 6).

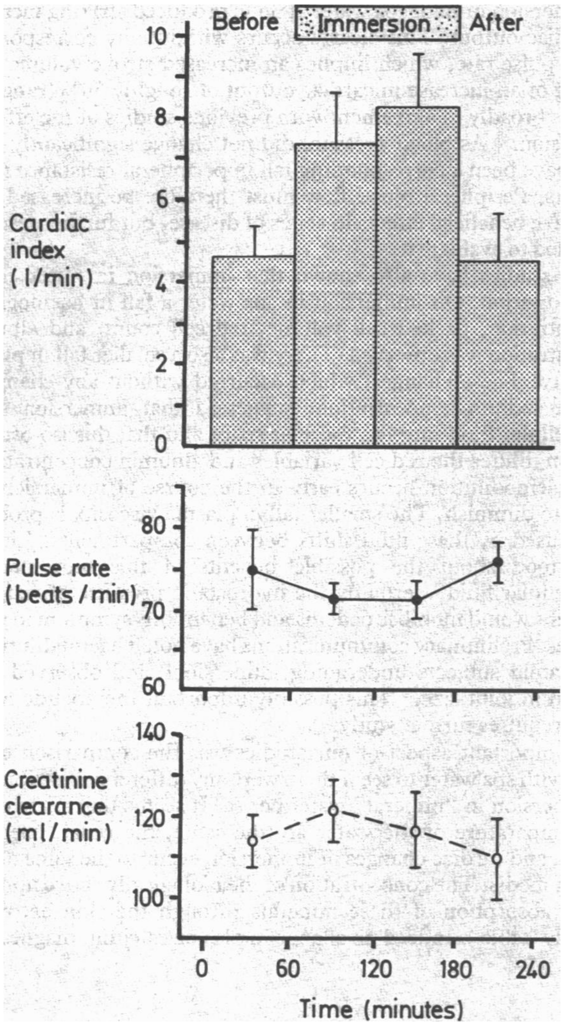

FIG 6—Cardiovascular changes on immersion in spa water.

Changes in haemodilution

A highly significant fall occurred in the concentrations of all red cell indices (haemoglobin, packed cell volume, and red cell count) ($p<0{\cdot}001$), reaching a maximum fall during the first 30 minutes (fig 7). A small fall occurred in plasma viscosity from mean values before immersion of 1·60 (0·018) cP to 1·53 (0·018) cP by 30 minutes, returning to 1·58 (0·021) cP after immersion, which just failed to reach significance ($p<0{\cdot}07$) ($n=4$). No change occurred in the plasma concentrations of electrolytes, calcium, phosphate, or magnesium. A âignificant fall in plasma albumin concentration was observed (from 44·5 to 41·5 g/l) ($p<0{\cdot}001$).

Cardiovascular changes

Immersion in spa water at 35°C resulted in a highly significant increase in cardiac index from 4·6 (0·7) l/min to 7·4 (1·1) l/min ($p<0{\cdot}001$). Pulse rate and blood pressure remained constant throughout immersion. Thus the increase in cardiac output was accompanied by an increase in stroke volume and a reduction in peripheral resistance (fig 6).

STUDIES WITH TAP WATER

The same subjects were studied under identical conditions with tap water. No significant differences were observed in the renal, haematological, or cardiovascular changes brought about by immersion when tap water replaced the spa water (fig 8).

Discussion

Immersion in spa water has been practised for centuries and is still a state subsidised medical facility in many European countries. The concept of "washing away disease" and the obvious symbolic importance of water probably contribute to an important placebo element in such treatment. Excessive and spurious claims (fig 1) and many charlatan practices that have grown up with spas[7] have helped to discredit them in the eyes of many scientific establishments.

Scepticism based on ignorance impairs scientific evaluation as much as do claims based on excessive faith. It is perhaps ironic that it is only as a result of mankind's need to conquer space that investigation into the basic physiology of immersion in water has begun. Early in the experience of space flight it became apparent that dehydration was a possible hazard, and during skylab flights plasma volume decreased by up to 15%.[8] The theory emerged that weightlessness resulted in a movement of blood from the limbs to the thorax. Engorgement of central blood volume was thought to trigger diuresis, natriuresis, and increased cardiac output. Immersion in "thermoneutral" water (35°C) also leads to a considerable renal response, and a similar mechanism of augmented venous return from the peripheries to the centre occurs.[2]

We studied immersion in Bath spa water at a temperature of 35°C and a seated depth of three feet over two hours. Bath spa water emerges from its source at 40°C, but temperatures in the bathing pools are equilibrated at around 35°C, which is the recommended temperature for hospital hydrotherapy pools. Much work has established that this temperature is "thermoneutral" and does not change the core temperature of the subject immersed.[2] The seated position and depth chosen in the present study allow comparison of our results with previous immersion studies. Interestingly, in the King's bath at Bath immersion was practised with patients seated in alcoves around the pool so that immersion would have occurred up to the neck in three feet of water. The length of time recorded for

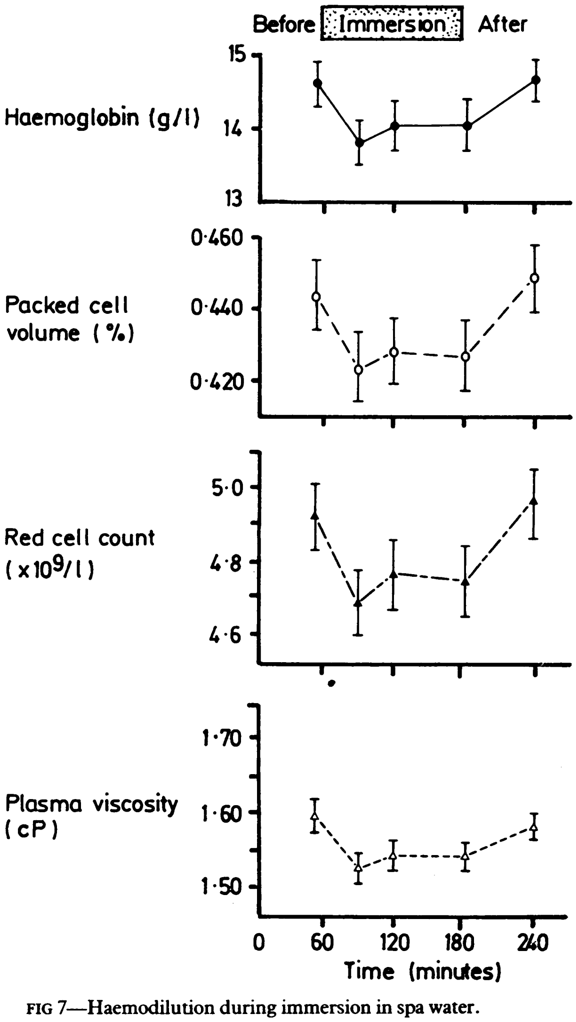

FIG 7—Haemodilution during immersion in spa water.

therapeutic immersion seems to have varied considerably but certainly periods of up to three hours have been practised.

Our study of immersion in Bath spa water resulted in similar renal effects, with significant diuresis and natriuresis. These occurred without an increase in glomerular filtration (measured by creatinine clearance). Other workers have described hormonally mediated tubular mechanisms such as suppression of antidiuretic hormone and the renin-aldosterone system.[9] The concomitant kaliuresis on

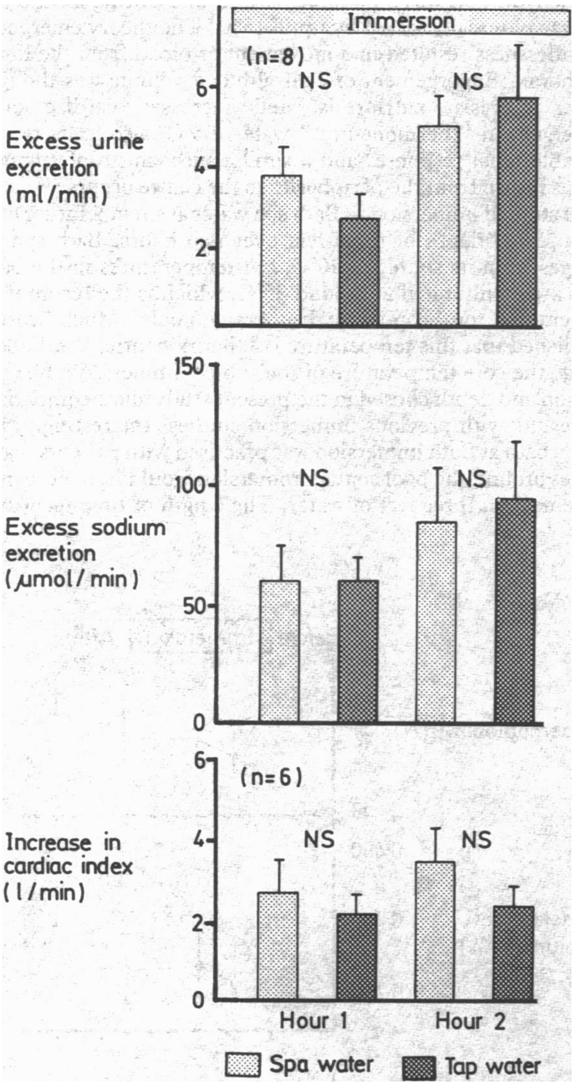

FIG 8—Comparison of changes in spa water and tap water.

immersion implies that the increased sodium excretion is not due entirely to suppression of the renin-aldosterone system.[10] Other mechanisms perhaps acting directly on proximal tubules have been proposed, such as natriuretic factors,[11] renal prostaglandins,[12] or the kallikrein-kinin system.[13]

While the renal changes induced by immersion are interesting and their complex hormonal background stimulating to the researcher the importance of these effects in states of disease still has to be elucidated. The amount of water and sodium excreted on immersion is small compared with the effect of powerful diuretics available today. For James Crook in 1764,[1] however, disabled by his dropsy (probably decompensated liver cirrhosis), a small effect would have been better than nothing. It is also interesting to note that while spa treatment was recommended for chronic oedematous conditions these early workers recognised that immersion with acute heart failure was dangerous,[1] presumably by further increasing a high central venous pressure.

Immersion in Bath spa water at 35°C produced striking increases in cardiac output. This clearly occurs without any corresponding rise in pulse rate, which implies an increased stroke volume. Our finding of an increase in cardiac output of roughly 50% (range 30-85%) is broadly in agreement with previous studies of the effect of immersion.[4-6] As blood pressure did not change significantly there must have been a corresponding fall in peripheral resistance in the subjects. Peripheral blood flow must therefore be increased; this may have beneficial effects in states of disease, but further research is needed to evaluate it.

Our studies have also shown that immersion in water causes haemodilution. On immersion in spa water a fall in haemoglobin concentration, packed cell volume, red cell count, and albumin concentration was observed. There was also a smaller fall in plasma viscosity. These changes, which occurred without any change in plasma sodium concentration, suggested that immersion shifts extracellular fluid into the vascular space and that this iso-osmotic solution dilutes the red cell variables and albumin concentration.[13] This haemodilution occurs early in the course of immersion and seems to diminish. The smaller fall in plasma viscosity is probably also caused by these fluid shifts between compartments. Little is understood about the possible benefits of this movement of extracellular fluid. Certainly the hydrostatic pressure of water on the limbs would mobilise oedema and benefit this symptom in many diseases. Preliminary communications have noted haemodilution in rheumatoid subjects undergoing immersion[14] and observed a reduction in joint size.[15] This possibly important therapeutic mechanism requires further study.

An important aspect of our studies was the comparison of tap water with spa water to see if there were any differences attributable to immersion in "mineral" water per se. It seems that if the depth and temperature of the water are the same, the renal, haematological, and cardiac changes of immersion occur to the same degree in both media. The concentration of the biologically active minerals makes absorption of these minerals through the skin extremely unlikely (table). Indeed no change in plasma calcium, magnesium,

Chemical composition (mg/l) of Bath spa waters (minerals) compared with plasma concentrations in man. (From Judd Lewis, 1936)

	Spa water	Extracellular fluid/ plasma	Tap water
Cations:			
Sodium	177·3	3100	37·6
Potassium	15·4	137	4·7
Magnesium	51·0	18	27·5
Calcium	391·8	85	196·1
Copper	0·04	0·7	
Zinc	0·01	0·05	
Lead	0·01	<·001	
Iron	1·45	0·5	0·03
Anions:			
Chloride	277	3368	52·36
Sulphate	1001	9	
Bicarbonate	192·8	1525	
Fluoride	4·3		0·17

or sodium concentrations was observed in our study. Whether the drinking of these mineral waters leads to significant changes in body content and has separate effects on physiology in health and disease remains an open question.

In conclusion, we tend to agree with the observations made 250 years ago by Friderick Hoffman, a Fellow of the Royal Society, that with regard to immersion "the chief virtues of medicinal springs are, in a great measure, owing to the Water itself, independent of their solid ingredients; and pure elementary water is an almost universal medicine." Whether water immersion is the "almost universal medicine suited to the cure of all diseases" as this early author goes on to claim, requires further scientific validation. What is certain is that a proper understanding of the physiology and pathophysiology of immersion is the important first step.

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Organ transplantation: from laboratory to clinic

R Y CALNE

Imagine the state of surgery in large urban centres when Lister began his work. Putrefaction of wounds was common and pus was regarded as "laudable" since it showed a reaction on the part of the patient, while sepsis without pus usually heralded death, which was the expected outcome from compound fractures and nearly half of simple elective procedures.

When Lister was beginning to grapple with surgical sepsis the work of Pasteur was brought to his attention and the nascent science of bacteriology provided Lister with a platform on which to base his scientific clinical studies. He developed a practical method of killing bacteria so that they did not colonise wounds and his demonstration of the effectiveness of his antiseptic technique of surgery and wound dressing was based on a small series of patients. Today his work would be regarded as unacceptable to any reputable scientific journal, as it did not consist of a randomised controlled trial with statistical assessment. Many of his contemporaries were sceptical of the results obtained, but gradually the facts overcame rhetoric as they always will do in the end. Lister's life was punctuated with many disappointments, and there was a time when he was subjected to ridicule. He lost favour with Queen Victoria over experiments on animals. The Queen exerted inappropriate pressure on Lister to denounce medical research involving animals, and in a very long and courteous letter of reply Lister ended with the following words:

"I have myself often performed experiments upon the lower animals, and that, if I have been privileged in my professional career to do anything for the good of my fellow men, more is to be attributed to these experiments than to any other work in which I have been engaged."

Because of the opposition to vivisection in Britain Lister went to France to perform important experiments. Lister's perseverance was eventually rewarded by recognition of the value of his work in his lifetime. Elective surgery became a safe and acceptable practice and the doors were opened to a renaissance in surgery, with all the highly developed branches of the art owing a direct debt to the elimination of operative sepsis.

Organ transplantation is a branch of surgery that is still young and, though pale in reflection to the importance of Lister's achievement in the control of surgical sepsis, bears some similarity to his life's work.

Based on the Lister Oration given on 21 May 1985.

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Death sentence

When I was a medical student terminal renal failure was a death sentence: all that could be done for the patient was to see to his comfort with sedative drugs. Liver and cardiac failure were similarly lethal, and even now with the best possible control some insulin dependent diabetics become blind and develop renal failure. It is fortunate for these patients that surgeons considered their plight and conceived of the possibility of treatment by organ replacement.

As a medical ward clerk working in Bright's old hospital, taking care of a young boy with terminal Bright's disease, I remember asking the consultant physician whether the patient might be treated by a kidney transplant. He told me that such a procedure was impossible but on further questioning he could not tell me why and similar inquiries to other clinicians met with the same response. In the next few years important clinical investigations were performed at the Peter Bent Brigham Hospital in Boston in Dr Francis Moore's department. A young surgeon, David Hume, supported by the nephrologist, John Merrill, transplanted a series of kidneys taken from dead donors, or so-called "free" kidneys removed in the course of other operations, into patients with chronic renal failure. Despite no serious attempts at immunosuppression, apart from giving small doses of steroids, some of these kidneys functioned for a surprisingly long time compared with the findings in animals in whom rejection of kidneys occurs between seven and ten days. The longest function in this clinical series was five and a half months. Hume and Merrill thought that the chronic uraemia from which the patients suffered may have contributed to their